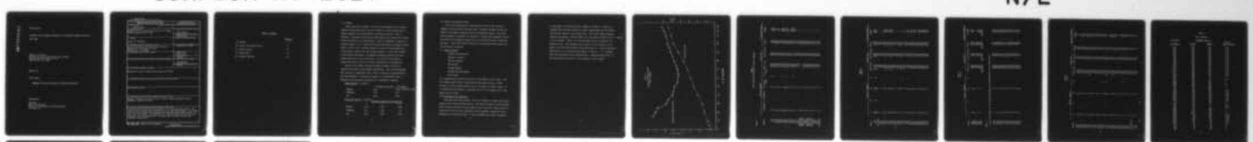
AD-A037 683 ARMY FACILITIES ENG SUP AGCY FT BELVOIR VA RES & TEC DIV 5/3

A REPORT ON THE ECONOMIC FEASIBILITY OF AN ENERGY...ETC.

MAR 77 KUKIELKA, CASIMIR A.

UNCLASSIFIED USAFESA-RT-2027 N/L

1 OF 1
ADA
037683



END

DATE
FILMED
5-77

ADA037683

FESA-RT-2027

A REPORT ON THE ECONOMIC FEASIBILITY OF AN ENERGY CONTROL SYSTEM FOR FORT KNOX

Casimir A. Kukielka
US Army Facilities Engineering Support Agency
Research and Technology Division
Fort Belvoir, VA 22060

March 1977

Final Report

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Prepared for:

Fort Knox
Facilities Engineer
Office of Environmental and Energy Control
Fort Knox, KY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FESA-RT-2027	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Report on the Economic Feasibility of an Energy Control System for Fort Knox		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER FESA-RT-2027
7. AUTHOR(s) Casimir A. Kukielka		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Facilities Engineering Support Agency Research and Technology Division Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE March 1977
		13. NUMBER OF PAGES 14 pages
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Energy, conservation, energy control systems, energy management systems, economics, economic analysis.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Fort Knox was evaluated for the economics of an energy control system. The minimum simple payback determined was 4.21 years for 74 buildings. The minimum life cycle cost payback period determined using DAEN-MCE-U escalation was 4.9 years for 74 buildings. A combination of a central control system and microprocessors will have paybacks of 3.54 years and 3.78 years for the same scenarios respectively.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

1.0 Summary

Three cases were evaluated. The first two considered only a central computer based system, while the third looked at a system consisting of a central computer with microprocessor on marginal buildings. Case 1, (Optimal), represents the fastest possible payback and involves 65 buildings controlled centrally via minicomputers. Case 2, (Breakeven), extends the building number to 115, matching the Energy Conservation Investment Program (ECIP) criteria. Case 3 (Mixed) considers a mixture of both central and local control, though it has the fastest payback it is the least flexible of the options considered. Two methods of economic analysis were used, simple payback and life cycle costing. The results of the analysis appear below (See Section 5 for further explanation of the economics).

Energy saving schemes included equipment shutdown, outside air reduction and shutoff, and enthalpy optimization. Lack of data prevented the inclusion of temperature reset, chiller, and boiler load optimization and load management. Although the hospital is an appreciable load, a separate study examining the hospital as a candidate is required.

Simple Payback (in years)

	A (Project cost only)	B (Project & recurring costs)
Optimal	4.21	6.76
Breakeven	5.71	9.11
Mix	3.54	5.67

Life Cycle Costing (in years)

	Escalation Scenarios (see page 14)		
	I	II	III
Optimal	5.73	5.16	4.90
Breakeven	8.2	7.26	7.5
Mix	4.72	4.39	3.78

2.0 Generic System Description

The initial Energy Control System suitable for Fort Knox should be capable of performing the following tasks: Equipment Shutdown, Outside Air Reduction & Shutdown, Enthalpy Control and Temperature Reset. The system must be capable of expanding its function to include load management routines and preventive maintenance program plus have available space for additional buildings. These requirements necessitate a mini-computer base system, the following one is proposed.

2.1 Central Console

Central Processing Unit

Operator's Console

16K Mini-computer

CRT Terminal

Program Package

256 Word Periphal Memory

Line Printer

It is assumed that the central console will be housed in the FE Shop. This will require modification of approximately 200 square feet and a 15KVA inverter to protect against memory loss in the event of a power outage. It is assumed the mini-computer is dedicated to and is an intergal part of the energy control system.

2.2 Buildings to be Controlled

Three cases have been studied. The first considers a totally centralized system with the fastest payback period. The second includes all the buildings which can meet a maximum six year payback criteria and still remain centrally controlled, while the third considers a central automatic system with micro-processors on marginal buildings. A plot of payback and initial investment

vs the number of building for Case 1 appears in Figure 1. The plot is arranged with buildings having the fastest simple payback on the extreme left and the slowest on the extreme right. The cost of common equipment (central minicomputer, central modoms, etc), has been excluded since it is common to all buildings. Table 1 lists the buildings used in the optimal and breakeven cases. The breakeven case includes all the buildings in the optimal case plus the buildings listed under Case II. A list of buildings controlled via local microprocessor appear in Table II. It is assumed that the microprocessors cost $1200.00 each. These buildings (Table II) have been grouped with Case 1 as an example of a mixed system.

FIGURE 1
CENTRAL COMPUTER SYSTEM
SIMPLE PAYBACK

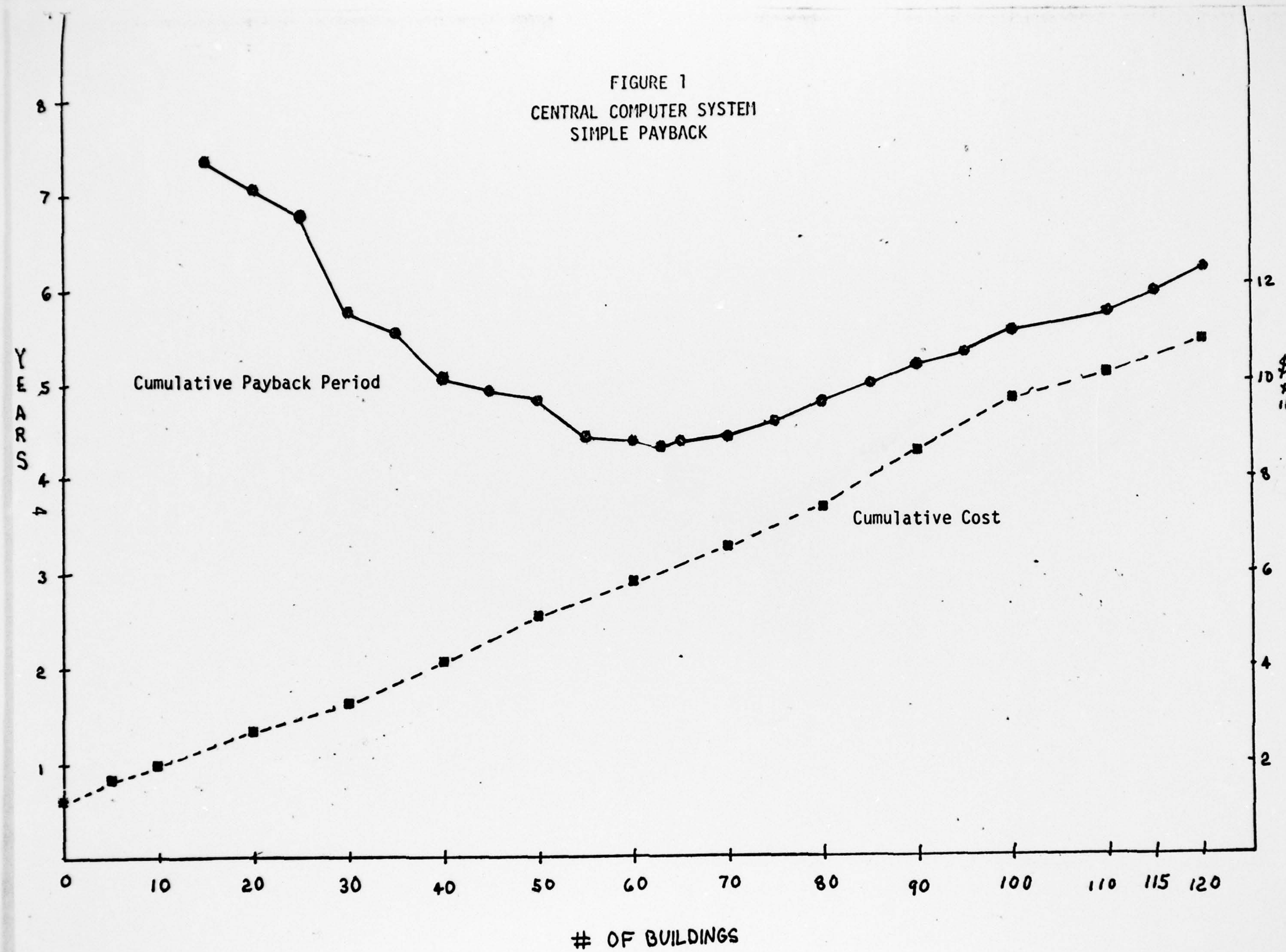


TABLE I
Buildings Controlled Via Central Computer

CASE I

BLDG #	Points (number)				Costs ($)		Savings ($/year)	
	B (binary)	A (analog)	SS (start-stop)	R (re-set)	Point Cost	Local Wiring	Winter	Summer
63	8		7	1	5210	460	584	962
77	9		8	1	5870	560	948	578
1110	9		8	1	5870	460	1846	1105
1376	1		1		660	100	460	--
2369	10		10		6600	610	1472	881
5932	1		1		660	100	310	---
204	8		7	1	5210	680	430	800
1109	10		9	1	6530	710	1945	3264
1306	11		10		7190	810	958	477
1307	13		12	1	8510	810	1878	3418
1310	4		4		2640	400	858	--
1467	6		6		7190	810	1828	3418
1468	10		9	1	6530	710	958	1790
1474	7		6	1	4550	360	600	992
2371	1		1		660	100	360	--
6541	3		3		1980.	200	633	---
6542/6543	2		2		1310	200	1200	--
6544/6545	4		4			400	1200	--
6546/6547	2		2		1310	200	1200	--
6548	3		3		1980	300	633	--
6550/6551	4		4		2640	400	1200	--
6552/6553	3		3		1980	300	1100	--
6554/6555	2		2		1320	200	1200	--
6556/6557	4		4		2640	400	1233	--
6558	1		1		660	100	600	--
6578	2		2		1320	200	613	--
6579	1		1		660	100	604	--
6580/6581	4		4		2640	400	1566	--

TABLE I
Cont'd

BLDG #	Points (number)				Costs ($)		Savings ($/year)	
	B	A	SS	R	Point Cost	Local Wiring	Winter	Summer
126	26	3	20	4	16,518	2880	7478	3281
127	26	3	20	4	16,118	2880	1307	6632
1477/1478	2		2		1320	200	836	--
1481	1		1		660	100	244	--
2382	1		1		660	100	222	--
6549	1		1		600	100	222	--
1724	18		18		11,880	1210	5330	3024
1726	7		7		4620	620	1332	756
1730	6		6		3960	560	1882	811
2010	18		18		11,880	1210	2132	1209
2368	17		17		11,220	1160	990	562
9297	6		5		3560	500	916	--
9298	6		5		3560	500	916	--
9306	5		4		3560	500	916	--
9307	7		6		3380	600	1629	--
9308	17		16	1	10,820	1600	5575	---
1174	1		1		660	100	1178	--
1384	5		5		4620	700	404	212
850	1		1		660	100	3973	--
1227	12		10	1	7440	840	2525	1632
2372	1		1		660	100	222	--
1610	13		13		1030	1030	3896	1306
2385	6		6		3960	410	1258	171
4022	5		5		9300	460	1567	1349
2421	1		1		660	100	2283	--
2442	6		6		3960	560	1500	2193
4555	13		13		8580	860	2039	565
5917	9		9		3960	760	1803	490
5940	8		8		7260	560	1806	500
5942	7		7		4260	460	1806	500
6012	8		8		5280	560	1806	500

TABLE I
Cont'd

	Points (number)				Costs ($)		Savings ($/year)	
BLDG #	B	A	SS	R	Point Cost	Local Wiring	Winter	Summer
6018	8		8		5280	560	1806	500
6590	13		13		8580	800	1451	402
6649	1		1		660	100	987	--
6591	1		1		660	100	1053	--
7060	7		7		4620	460	1369	685
5928	1		1		3960	410	1831	1231
					$287,621	$42,410	$93,736	$44,280

CASE II

Case II includes all the above buildings plus the additional ones listed below:

BLDG #	B	A	SS	R	Point Cost	Local Wiring	Winter	Summer
1482	7		7		4560	360	600	223
297	7		7		4620	400	592	250
1484	7		7		4620	360	600	223
1485	7		7		4620	360	600	222
1486	8		8		5280	610	633	236
1475	9		9		5940	610	683	236
488	6		6		3960	360	381	228
298	8		8		5280	510	443	186
1483	9		9		5940	610	633	236
1479	9		9		5940	610	633	236
1480	9		9		5940	360	600	233
2374	9		9		5940	360	600	223
2375	9		9		5940	360	600	223
2376	9		9		5940	360	600	233
2377	9		9		5940	360	600	233
2378	9		99		5940	360	600	233

TABLE I
Cont'd

BLDG #	Points (number) B	A	SS	R	Costs ($) Point Cost	Local Wiring	Savings ($/year) Winter	Summer
2380	11		11		5740	360	600	223
4770	2		2		5940	360	600	--
5910	18		18		5940	360	600	223
296	6		6		3960	360	337	192
2368	17		17		11,220	1160	990	562
5949	7		7		4620	360	404	212
6289	7		7		4620	360	430	256
203	37		36		24,350	2560	1551	1353
1325	16		14		9760	810	216	1078
853	8		8		5280	510	443	189
2000	7		7		4620	740	404	212
1476	6		6		3960	360	359	134
2373	11		11		7210	610	633	236
6539	7		7		4620	460	250	275
5931	8		7	1	5350	460	256	145
5923	7		6	1	4550	580	337	134
65	19		19	1	12,540	810	716	425
4554	17	3	15	2	12,628	1280	324	741
7741	1		1		660	100	90	--
5951	9		9		5940	560	315	219
5916	18		18		10,880	720	760	4464
5950	9		9		5940	560	316	214
1102	6		6		3960	410	2007	1349
6013	5		5		3300	460	55	91
6591	1		1		660	100	160	--
5925	7		6	1	4550	580	160	108
5934	7		6	1	4550	580	160	108
5933	7		6	1	4550	580	160	108
5924	7		6	1	4550	580	160	108
5918	7		7		4620	460	91	85
1173	7		7		4620	510	112	62
New Library	6		6		5140	830	22	92
1117	7		7		4620	360	16	38
855	6		6		3960	360	16	28
856	6		6		3960	360	16	28
	860	821						

TABLE II

LOCAL CONTROLS

BUILDING #

BUILDING #	SAVINGS ($/year) WINTER	SUMMER	(Years) SIMPLE PAYBACK
1482	600	223	1.46
297	592	250	1.43
1484	600	223	1.46
1485	600	222	1.46
1486	633	236	1.38
1475	683	236	1.33
488	381	228	1.97
298	443	186	1.91
1483	633	236	1.38
1479	633	236	1.38
1480	600	233	1.44
2374	600	223	1.44
2375	600	223	1.44
2376	600	233	1.44
2377	600	233	1.44
2378	600	233	1.44
2380	600	223	1.75
4770	600	--	1
296	337	192	2.27
2368	990	562	1
5949	404	212	2
6289	430	256	1.8
203	1551	1353	1
1325	216	1078	1
853	443	189	1.9
2000	404	212	1.95
1476	359	134	2.43
2373	633	236	1.38
6539	250	275	2.29
5931	256	145	3.0
5923	337	134	2.55
65	716	425	1
4554	324	741	1.2
7741	90	--	3.3
5951	315	219	2.25
5916	760	446	1
5950	315	214	2
1102	2007	1349	1
5925	160	108	4.48
5934	160	108	4.48
5933	160	108	4.48
5924	160	108	4.48
5918	91	85	6.82
1173	112	62	6.9
1117	16	38	6
855	16	28	6
856	16	28	6

3.0 Energy Savings

The Automation and Centralization of Facilities Monitoring and Control System Manual, (Reference 1, ECS Manual) outlines 10 energy savings schemes, (See ECS Manual, Chapter 4). Only four schemes: equipment shutdown, outside air reduction, outside air shutoff and enthalphy optimization were credited toward ECS savings. Lack of data prevented analysis of equipment optimization. Individual equipment performance curves and building heating and cooling load curves would be needed to properly model the system. The buildings savings were calculated for the applicable schemes since the building's HVAC systems weren't compatible with all schemes mentioned above. Savings attributed to each building can be found in Table 1.

4.0 System Cost

The system cost can be broken down into two categories, non-recurring, or the initial capital investment and recurring cost which includes salaries, training, and operation and maintenance. A typically priced system was chosen for analysis. An itemized list of non-recurring and recurring costs appear below:

4.1 Non-Recurring

4.1.1 Central Console

Processor Cost	$83,000
Central Processing Unit	
Operator's Console	
16K Mini-computer	
CRT Terminal	
Program Package	
256 Work Periphal Memory	6,300
Line Printer	10,500
	$99,800

To properly house the computer equipment, improvements must be made to the facility, estimated at $25/sq ft and an inverter to protect against loss of memory during a power outage was estimated at $1000/KVA. Thus the cost of the control room can be set at:

Central Console	$ 99,800
Renovation	5,000
Inverter	15,000
	$119,000

In addition to the above cost, remote points, remote panels, remote modems, central modem and wiring cost must be considered. For new structures, point cost need not be counted since they were included in the building design.

4.1.2 Remote Points

The number of each point type was determined to be:

		NUMBER OF POINTS			
POINT	COST/POINT	OPTIMUM	BREAKEVEN	OPTIMUM	BREAKEVEN
Start/Stop	$400	398	821	$159,200	$328,400
Reset	300	18	22	5,400	7,260
Analog	406	6	9	2,436	3,654
Binary	260	426	860	110,760	223,600
TOTAL				$277,796	$562,914

4.1.3 Local Wiring

In calculating local wiring cost it was assumed for points in the basement that a ten foot run from a point to the remote panel was required, fifty feet for dampers and fifteen feet for all other points. For building sharing remote panels it was assumed an additional 75' of wiring was required to connect the buildings. All remaining calculations concide with procedures recommended by the ECS manual. The local wiring cost for the optimal and the six year payback conditions came to $44,416 and $70,700 respectively.

4.1.4 Remote Panels and Modems

Due to the high cost of wiring, the majority of building have individual remote panels. In some cases where the buildings are close and the number of points is low, the panels have been shared. Since telephone lines are being used for transmission each panel will require a remote modem. One central modem is required for every sixteen remote modems. To tie the system to the computer, 63 remote panels ($2000 each) are required for the optimal case and 115 remote panels for the 6 year payback case. Thus 63 & 115 remote modems, $325 each and 3 and 8 central modems priced at $5000 each must also be included. Thus the total cost of the communication links for each scenario is $161,00 and $307,000 respectively.

4.2 Total Capital Investment

The total capital investment cost will consist of central system, remote points, local wiring and the communication link prices. The total cost for both scenarios is calculated below:

	Optimal	Six Year
Central Room	$119,800	$ 119,800
Remote Points	277,796	562,914
Local Wiring	42,410	70,700
Communication Link	161,475	307,375
TOTAL CAPITAL INVESTMENT	$601,481	$1,060,789

5.0 Economic Analysis

Two approaches will be used in the economic analysis, simple payback and life cycle costing.

5.1 Simple Payback

Simple payback is the project funded cost divided by the yearly savings. The total project cost divided by the yearly savings was calculated also.

5.1.1 Project Funded Cost Method (A)

Optimal Case

$$\text{Simple Payback} = \frac{\text{Project Funded Cost}}{\text{Total Savings/Year}}$$

Simple Payback = $601,000/$98,423 + 44,280) = 4.21 years

Breakeven Case

Six Year Payback = 1,060,000/185,591 = 5.71 years

Mixed Case

(657,400/185,591)= 3.54 years

5.1.2 Total Project Cost Method (B)

Besides the initial capital investment, recurring cost can be considered when estimating the system price. This includes maintenance, labor and training. The calculation method follows:

		Optimal	Six Year
Maintenance	5% of initial capital investment	30,050	53,000
Labor	N x 1.24 x 1.29 x 14,000 (N = shifts)	22,400	22,400
Training	1500/man bi-annually	1,500	1,500

$$\text{Simple Payback} = \frac{\text{Total Project Cost}}{\text{Yearly Savings}}$$

Let N = Simple Payback Period. Assume training cost will be $750/year.

$$N = \frac{\text{Initial Investment + Maintenance (N) - Maintenance + Labor + Training}}{\text{Yearly Savings}}$$

Therefore,

$$N = \frac{\text{Initial Investment - Maintenance Cost}}{\text{Yearly Savings - Labor - Maintenance = Training}}$$

Optimal Case

N = (601,000 - 30,050) / (138,000 - 22,400 - 30,050 - 750)

N = 6.76 years

Breakeven Payback Case

N = (1,060,000 - 53,000) / (186,683 - 22,400 - 53,000 - 750)

N = 9.11 years

Mixed Case

It is assumed that the increased labor requirements to maintain the remote microprocessors will be no more than one man year ($22,400). This is considered very adequate.

(657,000 - 32,850) / (185,591 - 44,800 - 30,050 - 750) = 5.67 years

5.2 Present Worth Life Cycle Costing Method

It is assumed in all cases that the system will be operational in 1981. Inflation is assumed to be 5%.* The initial capital investment is taken at the midpoint of construction. Three cases were considered.

The following parameters were used in the life cycle analysis for the three scenarios.

	CASES		
	I (AR 11-28)	II (TRADOC)	III**(DAEN-MCE-U)
Heating Oil Cost	$2.82 MBTU	$2.92 MBTU	$3.16 MBTU
Heating Oil Escalation	7%	9%	10% - 4%
Electricity Cost	$.021 KWH	$.021 KWH	$.026 KWH
Electric Cost= Escalation Factor	10%	10%	20% - 9%

Applying the methodology discussed in the ECS Manual the following results were obtained (payback in years).

	I	II	III
Optimal	5.73	5.16	4.90
Breakeven	8.2	7.26	9.81
Mixed System	4.72	4.39	3.79

*Chemical Engineering - Economic trends
**Escalation factors, first number escalation until 1980; second number 1981 and beyond straight line method of escalation employed.